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ABSTRACT

The document presents immediate and long range plans for the systematic injection of Symbolic Integrated Maintenance Systems (SIMS) and Fully Proceduralized Job Performance Aids (FPJPA) materials into the current technical order system and the inclusion of job-oriented training matched to FPJPA into the training system of the Air Force. The text is structured in consonance with a matrix which indicates the relationship between categories of data and the users, as well as the possible impact of job-oriented training on maintenance and personnel systems. The various categories examined include: maintenance technical orders (TO); FPJPA; non-troubleshooting (non-TS) and troubleshooting (TS) tasks; maintenance dependency chart (MDC) based aids for TS. Chapters examine the functional categories of information and directions; an analysis of effectiveness considering data, training, and personnel; proposed modifications to the Air Force technical order (TO), training and personnel systems; implementation considerations. A summary, introduction, listing of 21 conclusions and 17 recommendations, and a project update are included. It is stated that the development and proper utilization of a technical order system that integrated FPJPA into the TO system would greatly improve the quality of maintenance and reduce on-the-job training. (LH)

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AIR FORCE HUMAN RESOURCES LABORATORY

A PROPOSED MODIFIED TECHNICAL ORDER SYSTEM AND ITS IMPACT ON MAINTENANCE, PERSONNEL AND TRAINING

By

John P. Foley, Jr.

ADVANCED SYSTEMS DIVISION
Wright-Patterson Air Force Base, Ohio 45433

December 1975
Final Report for Period December 1974 – September 1975

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This technical report has been reviewed and is approved.

GORDON A. ECKSTRAND, Director
Advanced Systems Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

NOTICE

Most of the discussions, conclusions and recommendations stated in this technical report are based on an input cutoff date of June 1975. All of the discussions, conclusions and recommendations are still valid. However, a few very important and positive implementation actions have taken place since that date, which are not reflected in the report.

1. The job guide manual, a type of fully proceduralized job performance aid (FPJPA) for non-troubleshooting tasks, has been designated as the only official Air Force data for "on aircraft" maintenance.

2. The evaluation of the effectiveness of the C-141 data has been expanded to include the impact on the personnel and training systems.

3. In addition to the job-oriented training being developed to match the C-141 aircraft data, the Air Training Command has established two job-oriented training efforts HASTYCHIEF and HASTYSPARK. HASTYCHIEF applies to the initial training of the aircraft mechanic on the C-130 Aircraft. HASTYSPARK currently applies to ground communications, electronics training, but may be expanded to other electronic maintenance training.

4. A draft specification has been developed for the Army which reflects a major portion of the draft specification, found in AFHRL-TR-73-43(I) (See ref. 11). It specifies a type of FPJPA for non-troubleshooting tasks, called the job performance manual, but a modified FORECAST (see ref. 22) type of aid for troubleshooting. It, also, specifies the content of the matching training to be given to newly enlisted Army personnel. The Army is now applying this specification to several of its weapons systems. The specification, as well as a technical report on the specified training/JPA trade off system, are now in press.

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This study represents an effort to synthesize the results of job performance aids and job-oriented training research together with promising potentials both proven and hypothesized. The categories of information and directions found in current maintenance technical orders (TO) are identified and classified. Their relationships to improved categories of data are indicated. The improved categories are found in fully proceduralized job performance aids (FPJPA) for non-troubleshooting (non-TS) and troubleshooting (TS) tasks, as well as in maintenance dependency chart (MDC) based aids for TS. Each category is considered in light of its unique contribution, or potential contribution, to improved maintenance when used by maintenance personnel with various levels of aptitudes, training and experience. The potential gains from the combining of FPJPA technology with job oriented

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training are discussed. Throughout the report, the fact is emphasized that both technologies are based on the systematic identification of maintenance tasks and the appropriate analyses of such tasks. Each category of data is, also, considered as to its utility for other users of TO categories; such as, supply and transportation specialists, operators, engineers, administrators, training specialists, and trainees. This systematic structuring of maintenance, TO, training, personnel and user factors resulted in a list of preferred TO categories which would improve maintenance but still meet the needs of other users. The preferred categories are: (1) FPJPA for non-TS tasks (job guide manuals), (2) FPJPA for TS tasks, (3) MDC with pictorial locators, (4) keyed schematics, (5) keyed information, (6) pictorials with locator grids, (7) aircraft wiring diagrams, (8) illustrated parts breakdowns (IPB), and (9) preservation, shipping and storage information. The state-of-the-art will support the immediate implementation of all of the categories except FPJPA for TS. They are now in advanced development and should soon be ready for implementation. The systematic considerations of this study provide the bases for recommendations concerning implementation of state-of-the-art job performance aids technology as well as for further research and development of other areas such as the coupling of FPJPA and job oriented training technologies. As with any work of this kind the projections, especially the hypotheses, reflect to some extent the experiences, insights, and biases of the author.

SUMMARY

Problem

In order to improve maintenance, and to reduce maintenance and personnel costs, the Air Force has been considering the inclusion of various types of maintenance aids into the technical order system. These include fully proceduralized job performance aids (FPJPA) for non-troubleshooting (non-TS) tasks, sometimes called job guide manuals; FPJPA for TS; maintenance dependency chart (MDC) based aids for TS; logic trees for TS; and symptom-cause charts for TS. In addition, combinations of job oriented training also have been suggested. A logical question is: What gains, if any, can be expected from various mixes of technical order (TO) categories, types of training and types of personnel?

All of these proposals for change have had the maintenance man in mind, yet the TOs are used by other Air Force specialists. Other questions have been raised about the impact of proposed changes on the current Air Force maintenance, TO, training and personnel systems. Typical questions are: What should be the relationship between FPJPA and current TO system? Should they replace the current TOs for organizational and intermediate maintenance? Should separate TOs be produced in addition to FPJPA? If FPJPA and limited training were used extensively, who would be available to solve the small percentage of extremely difficult maintenance problems not covered by FPJPA? What types of TO material would be available for the solution of these problems?

Since each type of maintenance aid makes its own unique contribution to maintenance, the answers to these questions will change with different mixes of proposals. But valid answers to such questions should be available. In addition, the Air Force should have supportable recommendations for a systematic program for current implementation and for future research and development.

Approach and Results

The categories of information and directions found in current maintenance TO were ascertained and classified. The relationships of the improved categories of data to these TO categories were indicated. An inclusive matrix was developed which displayed all of these TO categories on the Y axis. On the X axis, were displayed maintenance personnel of varying levels of training and experience as well as other users of TO categories.

The discussions found in the report are structured in keeping with this matrix. Each category of data was systematically considered with relationship to its unique contribution or potential contribution to improved maintenance when used by the various types of maintenance personnel. Each category of data was also considered as to its utility for the other users of TO categories such as supply and transportation specialists, operators, engineers, administrators, training specialists and trainees. The projected effect for each discussed relationship is displayed by an appropriate symbol placed in the appropriate cell in the matrix. Projections were made on the bases of hard data obtained from controlled studies, when such hard data existed. Otherwise, they were presented as reasonable hypotheses to be tested by future studies. Since the results of many job performance aid and job oriented training studies were reflected in these considerations, summaries of such studies are included in the report. The projections, especially the hypotheses, also, reflect the experiences, insights and biases of the author.

Throughout the report, it was emphasized that the advanced JPA technology for maintenance as well as job oriented training technology are based on the systematic identification of maintenance tasks and appropriate analyses of identified tasks. This systematic structuring of maintenance, TO, training, personnel and user factors resulted in a list of preferred TO categories which would improve maintenance but still meet the needs of other users. It, also, provided a basis for recommendations concerning implementation of state-of-the-art FPJPA technology and recommendations for further research and development of other areas, such as, the coupling of FPJPA and job-oriented training technologies.

Conclusions

The following major conclusions are based on the analyses and resulting projections presented in the report.

1. It is envisioned that a full integration of FPJPA and other advanced type of technical data categories into the TO system to meet the needs of all users will ultimately result in the following categories of data for both *the organizational and intermediate levels* of maintenance: FPJPA for non-TS tasks (currently called job guide manuals), FPJPA for TS tasks, MDC with pictorial locators, keyed schematics, keyed information, pictorials with locator grids, aircraft wiring diagrams, illustrated parts breakdowns (IPB), and preservation, shipping and storage information. The development and proper utilization of a technical order system containing all of the above categories would greatly improve the quality of maintenance and greatly reduce on-the-job training. This would make personnel newly assigned to maintenance units effective on non-TS tasks almost immediately upon assignment.

2. With the exception of FPJPA for TS (and pictorials with locator grids) all of the above categories are officially authorized in some fashion as categories of data available to Air Force users. Since pictorials without grids are available as a category in current TOs, the addition of grids would be a minor change. The purely equipment oriented categories of data require only format specifications for their production and control. *But*, FPJPA and MDC, as well as job-oriented training, require the subproducts of job task identification and analyses of the identified tasks for their production and control. These analyses are the bases of these technologies. Until such subproducts become firm requirements in specifications, the technology has not been fully implemented.

3. The monitorship of the development of the subproducts of task identification and analyses; their evaluation and acceptance; and their proper application during the technical data development require an Air Force team of managers and technicians with special skills. Such a team of specialists was developed in the Aeronautical Systems Division at Wright-Patterson AFB, OH, during the JPA efforts for Vietnamization. After these efforts were completed, the members of this team were assigned other duties and their expertise was lost. This personnel requirement should be studied and appropriate action taken to prevent this from happening in the future. Such expertise must be developed and effectively utilized.

4. The effective implementation of the TO proposals of this report will require high level, positive, aggressive action supported by the necessary funds. Such an implementation requires the changes of attitudes and behaviors of too many people for it to come about just because the proposals are sound. Even though permissive format authorizations are now available for the development of FPJPA for non-TS tasks and for MDC, there is no firm official Air Force policy that these are the preferred categories of data. These preferred TO categories should be required for all new Air Force systems and subsystems and for key in-place systems and subsystems.

5. Action to implement FPJPA for TS will depend on the results of the advanced development efforts currently in progress. Trouble identification is the most difficult and expensive maintenance activity. Yet, few if any,effective actions have been implemented to increase troubleshooting efficiency.

6. Even though the job-oriented training technology has not been widely adopted by the Air Force, there is overwhelming evidence as to the success of the technology if properly applied. However, there have been no controlled studies which combine the job-oriented training technology with FPJPA technology. It is hypothesized that such a combination could result in greatly reduced training time for first term enlistees. This would require a very precise consideration of the FPJPA/training trade-offs during their development. The appropriate device for this trade-off is a structured task identification and analysis system. But, a required ingredient for the projected savings in *formal* training is the category of FPJPA for TS.

7. If, and when, FPJPA are injected into the Air Force system, they should result in substantial impact on the Air Force personnel and training system. No serious effort is now being made to study the possible impact of the FPJPA for necessary modifications in the Air Force training and personnel systems. It is hypothesized that hundreds of millions of dollars could be saved by the proper mix of FPJPA and job-oriented training together with the necessary modifications to the personnel system.

8. In addition to potential for reduction in regular formal training time, it is hypothesized that the FPJPA technology has potential for greatly reducing on-the-job, special and supplementary training. It also has great potential for the rapid buildup of forces in cases of national emergency, provided the FPJPA are available when the emergency arrives.

PREFACE

This report represents a portion of the exploratory development program of the Advanced Systems Division of the Air Force Human Resources Laboratory. The preparation of this report has been documented under Task 171004, Job Performance Aids for Air Force Maintenance Technicians, of Project 1710, Training for Advanced Air Force Systems. Work reported in this document was accomplished under work unit 17101025. Mr. John J. K. Klesch was task scientist. Dr. Ross L. Morgan was project scientist.

The author wishes especially to express appreciation to Mr. Lowell W. Thompson, formerly of the Policy Division of the Systems Directorate, Headquarters Air Force Systems Command, for his assistance in identifying the various users of maintenance technical orders and for reviewing an early draft of the report; and to Dr. Gordon A. Eckstrand of the Advanced Systems Division for his extensive comments which are reflected in the report.

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A PROPOSED MODIFIED TECHNICAL ORDER SYSTEM AND ITS IMPACT ON MAINTENANCE, PERSONNEL AND TRAINING

I. INTRODUCTION

This report presents both immediate- and long-range plans for the systematic injection of Symbolic Integrated Maintenance Systems (SIMS) and Fully Proceduralized Job Performance Aids (FPJPA) materials into the current technical order system. The plans, also, include the concurrent injection of job-oriented training, matched to the FPJPA, into the Air Force training system. Firm recommendations are made for the injection of SIMS type aids for troubleshooting (TS) and FPJPA for non-troubleshooting (non-TS) tasks since the current state of the technology will support such recommendations. The recommendations concerning FPJPA for TS tasks and job-oriented training matched to FPJPA are for the development and controlled tryout of hypotheses (developed in this report) as to the possible effectiveness of such technologies. Such hypotheses concern the gains to be made by the Air Force in decreased initial formal training times and increased job effectiveness for first term airmen. These hypotheses are based on syntheses and projections of published research findings. These syntheses and projections also reflect the experiences and insights of the author.

During the past twenty years several programs have been directed toward improving the effectiveness of technical orders (TO) as sources of job directions for maintenance at the organizational and intermediate levels. However, at the present point in time, the three main sources of new categories of maintenance directions and information have come from the Symbolic Integrated Maintenance System (SIMS) concept, the Air Force Presentation of Information for Maintenance and Operation (PIMO) Project and the ongoing work at the Air Force Human Resources Laboratory (AFHRL). The SIMS concept has produced a new TS tool, the maintenance dependency chart (MDC), as well as reformated schematic and theory of operation information. The PIMO project produced FPJPA for non-TS tasks and the AFHRL work has produced FPJPA for TS tasks.

In one sense, the SIMS effort started with the existing technical order materials and attempted to improve their format and content for maintenance use. The AFHRL work started with a study of the tasks of the maintenance job and developed new types of directions that would guide the performance of each type of task. The PIMO project contains elements of both these approaches. All have made contributions which, in the opinion of the writer, should be systematically incorporated into the Air Force technical order system.

In addition to helping maintenance technicians, TO serve packaging, shipping, transportation and supply specialists; administrators; curriculum planners; training, specialists and trainees; advanced design and service engineers; and operators. In view of this wide audience, one must ask to what extent should the interests of maintenance technicians influence the content of TO. Likewise, what should be the relationship between FPJPA and the current TO system? Should they replace the current TO for organizational and intermediate maintenance? Should separate TOs be produced in addition to FPJPA? Other questions often are asked concerning the possible impact of FPJPA on training. For example–if FPJPA were used extensively, who would be available to solve the small percentage of extremely difficult maintenance problems not covered by FPJPA? What types of TO material would be available for the solution of these problems?

One purpose of this report is to propose answers to these and similar questions based on an analysis of available information. For the purpose of this analysis, some key facets of this information have been structured into a somewhat complex matrix which is displayed in Table 4 (page 37). This chart indicates the relationship between categories of data and the users, as well as, the possible impact of job-oriented training on the maintenance and personnel systems. Section II, III and IV of this report are structured in consonance with this matrix. The report indicates the sources of bases of each item of information. It attempts to explain, expand and discuss the relationships indicated in symbolic form on this matrix. Conclusions and recommendations are made. *The reader is cautioned not to try to interpret the matrix without the aid of the following explanations and discussions.*

Another purpose of this report is to consider some of the problems concerning the implementation of the AFHRL technical data technology into the current Air Force structure and to present suggestions for expediting the implementation of this technology. Section V is devoted to this purpose.

II. FUNCTIONAL CATEGORIES OF INFORMATION AND DIRECTIONS

The principle functional categories of information furnished by traditional technical order (TO), conventional SIMS (23), MIL-M-38799 (16) technical data, MIL-M-38800 (15) data and FPJPA will be considered. These are displayed in Columns 2 through 7 of Table 4 (page 37). It will be noted that all of these types of data may be applied to both organizational and intermediate maintenance except those listed in Column 6 under specification MIL-M-38800 (15). Although the categories of data called for by this specification could be applied equally well to intermediate maintenance, the specification is currently limited to organizational maintenance.

For the purposes of this analysis, Table 4 (page 37) indicates that traditional technical orders provide three classes of task information: (a) step-by-step directions for a great many non-TS tasks for organizational and intermediate maintenance, (b) direction and information categories for the support of TS, and (c) other information. During the past decade the efforts which have been made to improve the usability of the procedures for the maintenance technicians have resulted in methods for ensuring the completeness of the instructions, and improving their relevance and efficiency for the support of maintenance. Before discussing these various changes for the support of maintenance, the relationship of users to technical orders categories and their relationship to each other will be discussed.

Users of Technical Orders

Three facets of these "TO to people" relationships will be discussed. These are the relative numbers of each type of user, the categories of traditional TO information used by each type of user, and the relative amount of use by each type of user during the life cycles of systems. For the purposes of this discussion, the information displayed in Table 4 (page 37) is summarized in Table 1.

Numbers of Each Type of User. An examination of Column 2 (Table 1) indicates the number of maintenance, supply, and transportation specialist as well as design engineers and communications operators. The numbers for the specialists and operators are the numbers of permanent party airmen authorized for the Air Force as of 31 January 1975. These numbers do not reflect civilian technicians or reserve technicians. Since the greater part of organizational and intermediate maintenance, as well as supply activities are performed by airmen, these figures can be considered as reasonably representative. The number of design and service engineers shown are the total of civilian engineers assigned in AFSC and AFLC as of May 1973. Numbers are not given for curriculum planners, trainers, trainees and administrators. Their relation to TOs, although extremely important, should reflect and support what the operational Air Force world is doing, and what the operational Air Force is doing is reflected by the other users listed. The communication operator career field has been included as representative of airmen operators in the Air Force. Of course, pilots are operators of aircraft. Since they have their own special documents, their number is not included in this analysis.

Consideration of the numbers in Table 1 alone leads to the conclusion that the technical order requirements of maintenance technicians should be given special treatment. There are 6 times as many maintenance men as transportation, shipping and packaging, personnel, and 26 times the number of maintenance men as design and service engineers.

Categories of TO Information Used. A further examination of Table 1 indicates that maintenance technicians use all the categories of information provided by the TO system. Supply and transportation personnel make extensive use of only two categories, namely the preservation, shipping and storage information, and the illustrated parts breakdown (IPB). Engineers can use these categories of information but are not as dependent on such information as are the maintenance, supply or transportation people. If the required information and data are not available, engineers usually have the capability for generating or

Table 1. **Categories of Maintenance Technical Data Users and Their Relationship to the Technical Data System**

(1) Types of Users	(2) Number of Users	(3) Relative Amount of Use	Categories of TO Info										
			(4) Procedures	(5) Block Diagrams	(6) Schematics	(7) Theory of Operation	(8) Pictorial Diagrams	(9) Flow Diagrams	(10) Symptom-Cause Charts	(11) Logic Diagrams	(12) ACFT Wiring Diagrams	(13) PS&S Info[a]	(14) IPB[b]
Maintenance Tech	162,843	Constant	*X	X	X	X	X	X	X	X	X	X	X
Packaging Spec Shipping Spec Transporation Spec	17,639	Limited										X	X
Supply Spec	25,705	Great										X	X
Design and Service Engineers	6,950	Periodic		X	X	X	X	X				X	X
Operators (Comm.)	10,954	Constant	X						X				
Curriculum Planners	—	— Periodic	X	X	X	X	X	X	X	X	X	X	X
Trainers	—	— Great	X	X	X	X	X	X	X	X	X	X	X
Trainees	—	— Great	X	X	X	X	X	X	X	X	X	X	X
Administrators	—	— Periodic	X	X	X	X	X	X	X	X	X	X	X

[a]Preservation, shipping and storage information.

[b]Illustrated part breakdown.

reproducing it. Many procedures that operators use are the same or similar to the equipment step-by-step checkout procedures used by maintenance technicians. As a rule, they use these procedures more often than maintenance technicians and, therefore, become more proficient in their accomplishment. In some cases, operators do a limited amount of maintenance. For such maintenance symptoms-cause charts are generally provided. (Operator instructions are usually packaged in separate documents from the maintenance documents).

Conclusions Concerning Use. It can be concluded that the TO system should meet the job requirements of maintenance technicians, the equipment operators, the supply specialists, and the transportation specialties throughout the life cycle of hardware. Design engineers have only periodic need for TO information during the life cycle of hardware.

Disregarding the more limited requirements for engineers, all TO categories are used by maintenance technicians and seven of the TO categories listed are used almost exclusively by maintenance technicians.

The preservation, shipping and storage information, as well as the IPB, are used by the supply specialists and the various transportation specialists.

An operator requires step-by-step procedures for operational tasks, but there is usually a smaller number of such tasks for the operator of a hardware system than step-by-step tasks for the maintenance technician.

Since there is such a large number of maintenance technicians and since they use the largest number of information categories, it is appropriate that special attention be given to the TO needs of the maintenance technician.

The Improvement of Technical Orders for Maintenance

There have been many efforts to improve the usability of technical order materials for maintenance. Shriver and Trexler (23) described and analyzed ten new concepts for electronic maintenance. Included in those ten are the SIMS concept and Shriver's own project FORECAST (21 and 22). The Air Force efforts have included project PIMO (20) which resulted in FPJPA (step-by-step procedures) for non-TS tasks and the work of the Air Force Human Resources Laboratory (5) which has resulted in FPJPA for TS as well as non-TS tasks. The information presented in the upper left-hand area of Table 4 (page 37) includes both current TO data and sources of improved TO data. The improvements include SIMS (23), the current MIL-M-38799 (16), MIL-M-38800 (15), and AFHRL FPJPA. These will be discussed in terms of procedures for non-TS tasks, information or procedures for TS and other information now offered by the TO system.

Step-by-Step Procedures for Non-TS Tasks

For many years TO for maintenance have included step-by-step procedures for a great many non-TS tasks such as checkout procedures; align, adjust and calibrate procedures; remove, replace, and repair procedures; and servicing procedures. No methods or standards were available to evaluate such procedures as to their completeness of coverage of all job tasks, to develop and evaluate such directions in terms of a standard language, to develop and evaluate standard pictorial location information to support the standard directions, and to determine a consistent level of detail for the information for all such directions in a TO. The research and development for maintenance procedures have produced the required methods and evaluative criteria. To reflect these improvements in the analytic matrix displayed in Table 4 (page 37), three types of procedures for non-TS tasks are described.

Type A Procedures.[1] These are step-by-step procedures, written in standard language, and having a uniform level of detail. Each step of such directions is keyed to an accompanying pictorial which indicates the appearance and location of all equipment items referred to in the step. The completeness of job coverage and uniformity of coverage for each job task is ensured by required task identification and task analysis subproducts. Later these subproducts become evaluative criteria for insuring the completeness of

[1] This is the author's classification which is explained in Table 4 (page 37).

the task coverage and directions for each task. An objective is to place all the necessary directions and information for performing the task at hand in front of the technician. When this is impossible, a cross reference is provided as to the location of the necessary information. Currently, there are three documents that reflect these requirements for the organizational level of maintenance MIL-J-83302 (14) and a similar draft specification found in Volume I of AFHRL-TR-71-53(I) (8). AFHRL has updated the content of this latter document in AFHRL-TR-73-43(I) (11). The updated documents reflect both the organizational and intermediate levels of maintenance as well as trade-off between training and FPJPA. The MIL-J-83302 developmental procedures were used during later developments of JPA for the Vietnamization program. MIL-J-83302 JPA were prepared for the C-7 Aircraft, for three aircraft engines, for two fire trucks, for one refueling vehicle and for Seek Point.[2] The Seek Point aids covered organizational and intermediate as well as depot levels of maintenance. The other systems covered only organizational maintenance. None of these examples reflected the trade-off between training and FPJPA.

Type B Procedures. Type B procedures have a similar appearance to Type A procedures. Both are made up of step-by-step procedures, in standard language. In both types the nouns in the step-by-step procedures are keyed to a pictorial which indicates the appearance of the item and its location. Type A procedures are developed under the much firmer and more binding content criteria previously described. B type procedures for some systems may be as effective as A type procedures if the contractor has writers with outstanding ability, or if the procedures have been subjected to an indepth "hands on" verification. But even these actions cannot insure complete task coverage. The original PIMO aids (20), as well as the early aids produced for Vietnamization (UH-1H, CH-47 and C-123), are examples of Type B procedures. As indicated in Table 4 (page 37), the use of the current MIL-M-38800 (15) would provide such B type procedures for organizational maintenance only.

Type C Procedures. Type C procedures are the step-by-step procedures traditionally found in TOs. They are not usually written in standard language, directions vary in length and complexity, and very few pictorials are used to support the written directions. From time to time efforts have been made by various individuals and groups to improve such instructions, but these improvements have never been applied consistently. Some of the more recent TOs contain Type B procedures for a limited number of tasks.

Summary and Conclusions Concerning Procedures for Non-TS Tasks. The adoption of Type A procedures for organizational and intermediate maintenance for any system would provide all the necessary job instructions for non-TS tasks now provided by Types B and C. The developmental criteria for Type A procedures, if properly followed, will ensure that such procedures are provided for all such tasks and that the directions are of uniformally high quality. Referring again to Table 4 (page 37), it should be noted that current TOs which are now in use in the field generally contain Type C procedures for both the organizational and intermediate levels of maintenance. The procedures generally used in conjunction with the SIMS or SIMMS, appeared in an older edition of MIL-M-38799. The current version of MIL-M-38799 applies only to TS, not to non-TS tasks. As stated previously, MIL-M-38800 provides for Type B procedures for the organizational level of maintenance. MIL-J-83302 provided for Type A procedures. AFHRL-TR-71-53(I) and its updating report (AFHRL-TR-73-43(I)) also provide for Type A procedures.

Directions and Information for TS

The isolation or location of faulty components in complex mechanical and/or electronic systems has always been an expensive process in terms of the technician time and the number of spare parts used. There is some evidence which indicates that many technicians have only a limited facility for troubleshooting systematically. When this limited systematic approach is not successful, they fall back on the removal and replacement of components until the system becomes operational (7). Although this shotgun approach usually works, it is very expensive in terms of the number of spare parts used, and the secondary damage caused by unproductive and unnecessary remove and replace actions. Table 2 provides an excerpt from Table 4 concerning directions and support information for troubleshooting. Column 2 lists the troubleshooting categories found in traditional TOs. Column 3 lists the categories of improved substitute categories provided by SIMS. Column 4 lists the improved substitutes provided by MIL-M-38799. Column 6 indicates that FPJPA for troubleshooting provide a new category that can be substituted for all the other categories. The relationships and sources of these various categories are discussed in the following paragraphs.

[2]Seek Point – A classified ground electronic system developed by the Electronic Systems Division for the VNAF. FPJPA were prepared for organizational, intermediate and depot levels of maintenance.

Table 2. **The Relationship of Key Technical Data Improvement Efforts Concerning Troubleshooting to Traditional Content Categories**

Guidance	TO	SIMS or SIMMS	Current MIL-M-38799	MIL-M-38800 Organization Level Only	AFHRL FPJPA
Troubleshooting Directions	Symptom-cause Charts			Sumptom-cause Charts	
	Logic Diagrams			Logic Diagrams	
		Type B MDC			
			Type A MDC		Fully Proceduralized Troubleshooting Aids Directions to isolate any faulty equipment item refleted in the m: intenance concept (Type A Procedures)
Troubleshooting Support Information	Block Diagrams				
	Schematics				
	Flow Diagrams				
	Normal Reading and/or Tolerance Charts				
		Blocked Schematics			
			Keyed Schematics		
	Theory of Operation				
		Block Information			
			Keyed Information		
	Pictorial Location Diagrams				
		Pictorial with Grids			
	Aircraft Wiring Diagrams				
	Illustrated Parts Breakdown (IPB)				

Traditional Directions for TS. Traditional TO provide symptom-cause charts and/or logic trees for troubleshooting guidance. At best, either of these items provide rather limited coverage to the problems facing a troubleshooter. Symptom-cause charts do not contain all the trouble symptoms that a system can develop and many times the number of causes displayed for a given symptom is not complete. Logic trees in their traditional form do not display all of the necessary information for each decision point. When using either of these directive items, the technician must make use of the items listed under informational support (Table 4, page 37). To successfully use these TO materials and get most TS tasks accomplished in a reasonable time, the technician must be highly trained. He must be extremely familiar with the TO information and with the function of each unit of the equipment under test. Except for a limited number of troubles, the technician is required to plot his own course of action.

Improved Directions for TS. The SIMS concept has substituted a much more powerful TS aid than either the symptom-cause chart or the traditional logic tree: the maintenance dependency chart (MDC). This MDC is in the form of a matrix. It is a structured presentation of both directions and information. On the Y axis of this matrix is placed a systematic step-by-step checkout procedure. When followed, this procedure will produce out-of-tolerance conditions or symptoms when the system is not functioning normally. On the X axis of this matrix is placed all of the functional units of the system. A rather complex set of sumbols is provided for the cells of the matrix which indicates the desired equipment responses for each step of the checkout procedure and identifies the set of functional units that can cause such an out of tolerance condition. But, once this set of functional units (dependencies) is identified, the technician must plot his own course for determining which functional unit in the set is faulty and to troubleshoot and to repair the faulty functional unit. *Great care must be taken in developing MDC to insure that each set of functional units is complete.*

MIL-M-38799[3] (15) reflects a greatly improved MDC. Each functional unit listed on the X axis is keyed to a pictorial which indicates to the technician how the functional unit looks and where it is located. All of the hardware items mentioned in the checkout procedures are also keyed to pictorials. These MDC were first developed for the UH-1H as part of the Vietnamization program. This type of MDC was later specified in MIL-J-83302 (14). The limited available research (20 and 23) indicates that either of these MDC is much superior to the symptom-cause chart or the traditional logic tree for a highly trained man with experience on the specific equipment or system.

Traditional Information for TS. In addition to the directions found in symptom-cause charts and logic trees a number of categories of information which support TS are usually presented in traditional TO. These categories are listed in the TO column of Table 2 and include block diagrams, schematics, flow diagrams, normal reading and/or tolerance charts, theory of operation, pictorial location diagrams, aircraft wiring diagrams, and illustrated parts breakdowns. Most of these items were developed to support the original manufacture of the hardware and, although they contain much information of use to the troubleshooter, they were not human engineered for his use, either as to format or organization.

Improved Information for TS. The HumRRO FORECAST Project, (21) and (22), and efforts such as SIMS resulted in improvements in organization of such information. The blocked schematic of the SIMS concept combined much of the information presented in TO block diagrams, schematics, flow diagrams and normal reading and/or tolerance charts. The TO schematics are reorganized and placed in blocks of shades of gray or blue. Each block (or sub-block) represents a black box or a functional unit of a black box. The TO theory of operation is reorganized into similar blocks so that the technician can more easily find a statement as to the operational function represented by each major block of the blocked schematic. In SIMS, the TO pictorial location diagrams are replaced by pictorials with location grids such as are found on

[3] Although MIL-M-38799 (16) does reflect the format called for by MIL-J-83302 (14), it does not require the uniform task identification and analysis procedures. This is an extremely serious omission which could result in incomplete MDC.

road maps. Due to the color requirement, the printing of block schematics and blocked information is expensive. In addition, many times a block is not large enough for complete functional information.

An outcome of the Air Force PIMO effort has been the use of keyed schematics and keyed information which are probably as effective as the SIMS colored blocks. Although this contention has not been subjected to a comparative experiment, keyed schematics and keyed information were used with success in the PIMO project. These keyed items are now specified in the current MIL-M-38799 for Air Force use. The improved organizational and presentation concepts of SIMS and MIL-M-38799 have greatly improved the utility of TO TS information for experienced personnel.

Complete Integration of Improved TS Directions and Information (FPJPA for TS). As stated above, the MDC provides step-by-step guidance to a *set* of functional units. But once the faulty set is identified, the technician must plot his own course for finding the faulty component within this set. FPJPA for troubleshooting have extended the step-by-step guidance beyond that provided by MDC to the isolation of any faulty components for which the technician has responsibility under the maintenance concept of the hardware systems. As in the FPJPA for non-TS tasks, these step-by-step instructions are keyed to pictorials which indicate the location and appearance of the hardware items, or items, referred to in each step. All of the required information items formerly found in the various information categories from TO are usually included at the required spot in the step-by-step procedure structure. This, of course, reduces search time and eliminates the requirement for the technician being familiar with all of the informational categories for TS found in the traditional TO.

III. AN ANALYSIS OF EFFECTIVENESS CONSIDERING DATA, TRAINING AND PERSONNEL

The analyses in this section are concerned with the relative effectiveness of the various categories of technical data on Air Force maintenance and training. The information concerning the new data categories and modified training represents the expected effectiveness of various combinations of data categories, personnel, and training. Two possible *sets* of *projections* of the effectiveness of the use of various categories of technical data are displayed in Table 4 (page 37). (Figure 1 indicates the bases upon which the maintenance effectiveness of the various categories of technical data are made.)

The *first* set (Column 9) represents the possible effectiveness of each category of technical data upon the average maintenance performance of personnel receiving current lengthy broad based training at the beginning of their careers before being assigned to the actual maintenance environment and on-the-job training. As of 31 January 1975, there were 162,843 maintenance technicians authorized in the Air Force. Of these, approximately 47 percent (75,744) are first enlistment 3 and 5 personnel; the number of authorized 3 levels alone is approximately 17 percent or 1/6 of this total. In practice, the number of 3 level personnel, actually assigned, varies from this authorized figure. This *first* set reflects current Air Force training practice. (The personnel figures were obtained from the Air Force Personnel Center, Randolph AFB, TX).

The *second* set (Column 10) has been included to project the effectiveness of the system in which training would be greatly reduced for first enlistment airmen. This would be accomplished by a very carefully determined trade-off between the content of the initial training program and the content of the FPJPA.

The Effectiveness of Technical Data Categories and the Current Training System

Data Supporting Non-TS Tasks

Type C Procedures. The step-by-step procedures found in traditional technical orders are reasonably effective with 5 level maintenance personnel who have been given adequate OJT on the actual equipment upon which they are working. Neither 3 level nor 5 level maintenance personnel without OJT on the specific equipment can normally perform most tasks. There is some evidence indicating that only a limited number of 5 and 7 level technician with outstanding ability and extensive experience can be fully effective with this type of data (7).

The effectiveness of *FPJPA for* non-TS tasks (Job Guide Manuals) was adequately field tested in the Air Force project entitled Presentation of Information for Maintenance and Operation (PIMO). This project started in 1964 and ended in 1969. The results of this project indicated that when using FPJPA experienced and apprentice maintenance personnel as well as personnel with no aircraft maintenance training or experience could perform non-troubleshooting organizational maintenance tasks on the C-141 aircraft without error (20). In April 1975, such aids were delivered to the Air Force for operational use on the C-141 and their use is being given further evaluation.

The PIMO Project also evaluated a modification of Symbolic Integrated Maintenance System (SIMS) type aids for organizational *troubleshooting tasks*. The aids developed for the C-141 aircraft included Maintenance Dependency Charts (MDC) as well as key schematics and keyed information. The results indicated that experienced maintenance technicians could find 90 percent more troubles on their first troubleshooting attempts than when using traditional Technical Orders (TO) (20). In addition, Air Force Logistics Command (AFLC) supported a rather broad based development and tryout of SIMS type aids in the early 60's. The aids developed for this project included traditional SIMS data blocked schematics and blocked information. The results of tryouts of these data were generally positive.

FPJPA for non-TS tasks (Job Guide Manuals) and SIMS type aids for TS tasks have been accepted as official Air Force technical order (TO) materials for many years; SIMS since 1968 and Job Guide Manuals since 1969. Their status has been that they have been available to requesting Air Force agencies provided that their requirement was justified and that sufficient funding was available. Their development has not been mandatory.

Although the results of exploratory development efforts have indicated that **FPJPA for TS** have a great deal of promise, these aids have not been accepted as official Air Force TO materials. Such FPJPA are currently being given a large scale tryout which should be completed by June 1976. FPJPA for TS have been included in the analyses of this report because of their potential for reducing the cost of maintenance and formal training for the Air Force. The projections as to their effectiveness are based: (a) on an experimental comparison of such aids used by high school students of high and medium aptitude and conventional TO materials used by highly experienced technicians (1) and (2); and (b) on a limited tryout of such aids used by inexperienced airmen in an off line situation at Altus AFB, Oklahoma (17). Both of these activities were Air Force Human Resources Laboratory projects. In addition, the successful use of fully proceduralized troubleshooting routines to the blackbox level in the Malfunction Analysis Detection and Recording (MADAR) system of the C-5 Aircraft increases the confidence of the author in the projections concerning FPJPA for troubleshooting included in this report.

Figure 1. **Hard data bases of job performance aid projections.**

Types A and B Procedures (FPJPA for Non-TS Tasks). Type A procedures and well made type B procedures should be reasonably effective, or better, with 3 level people (20). First enlistment 5 level should be fully effective using type A procedures and at least reasonably effective using type B procedures. Both types of procedures should be fully effective with 7 level technicians and 5 level people beyond the first enlistment (20). Technicians who have experience using such procedures on one system can be expected to perform reasonably well on another system provided the second system also has such procedures (20).

Recommendation A *Type C procedures of traditional TO should be replaced by Type A procedures (FPJPA) for all non-TS maintenance tasks for both the organizational and intermediate levels of maintenance.*

Data Supporting TS Tasks and Their Relation to Current Training

Traditional TO, TS and SIMS Categories with 3 Level Maintenance Technicians. Table 4 (page 37), Column 9 indicates, that with current training procedures, 3 level technicians cannot be expected to perform TS adequately using the TS directions and information found in traditional TO, in traditional SIMS, or MIL-M-38799 materials.

Traditional TO TS Categories with 5 and 7 level Maintenance Technicians. Generally first enlistment 5 level technicians can be expected to be only reasonably effective as troubleshooters on equipment for which they have been completely OJT'ed using traditional TO categories. Some second enlistment 5 level technicians and a good number of 7 level technicians are fully effective troubleshooters using this type of data. Even the highly experienced people at times resort to remove and replace actions rather than analysis to isolate faulty components (7).

Traditional SIMS TS Categories with 5 and 7 Level Maintenance Technicians. First enlistment 5 level personnel who are trained in the use of Type B MDC should perform troubleshooting reasonably well after OJT. The blocked schematic and blocked information also increase the effectiveness of first enlistment 5 level technicians provided they are thoroughly familiar with the layout of their equipment. Research has indicated that highly experienced technicians can perform TS faster with fewer errors when using SIMS type categories than when using conventional TO (20). For the purpose of this analysis this statement applies generally to 7 level and second enlistment 5 level maintenance personnel.

MIL-M-38799 TS Categories with 5 and 7 Level Maintenance Technicians. Type A MDC are keyed to pictorials and Type B are not. This feature of Type A MDC reduces the requirement for the technician to be thoroughly familiar with the names and locations of the functional units addressed in the MDC. This should increase their effectiveness for all levels of users and especially with first enlistment 5 level technicians. The keyed schematics called for by specification MIL-M-38799 are probably as effective for 5 level personnel as the SIMS blocked schematics and cost much less to produce. The keyed information in some cases may be even more effective than the blocked information since the amount of information need not be limited to the space provided by the SIMS sized block.

Fully Proceduralized Job Performance Aids for TS

FPJPA for TS have all of the format charcteristics of FPJPA for non-TS tasks (Type A Procedures). Since FPJPA are aimed at a much more complex part of the maintenance job, the projected payoffs from this portion of the technology can be expected to be much greater. Figure 1 outlines the hard data bases for these projections. The author is of the opinion that these projections are conservative if *quality* technical data are provided. However, since the large scale field testing of FPJPA for TS will not be completed until June 1976, these projections are presented as reasonable hypotheses to be tested.

Projected Advantages. Among the *projected* advantages of FPJPA for TS over TO, SIMS or MIL-M-38799 materials are the following.

1. FPJPA for TS will be *reasonably* effective for use by 3 level maintenance technicians. This would make 3 level maintenance technicians productive workers very soon after assignment to a unit. (This in itself would be a very cost effective gain since approximately 17 percent of the maintenance work force is currently at this level).

2. FPJPA also will make first enlistment 5 level technicians fully effective troubleshooters. (This also would result in a great gain in the usability of personnel with limited experience since approximately 27 percent of the maintenance technicians are in this category).

3. FPJPA will make the TS efforts of 7 level and second enlistment 5 level personnel more productive by reducing the number of ineffective remove and replace actions, by reducing the number of spare parts consumed, and by reducing the amount of secondary damage caused by the current excess remove and replace actions.

Although it is estimated that good FPJPA for TS will identify at least *95 percent* of the possible troubles for the intermediate level of maintenance and probably a higher percentage for organizational maintenance, there will be some troubles that cannot be anticipated. *A limited number of highly trained and experienced maintenance technicians must always be available to handle such troubles. For these situations, these backup men should have MDC, keyed schematics, and keyed information.*

Recommendation B. *If and when appropriate field tests confirm the author's expectations, FPJPA for TS should become part of the TO system. It is envisioned that such data would be the primary TS guidance and would be used by all 3, 5, and 7 level technicians for practically all TS activities for organizational and intermediate levels of maintenance.*

Recommendation C. *Type A MDC, as well as keyed schematics and keyed information, should be a part of the TO system. Until FPJPA for TS are available, these categories of data would serve as the primary TS data. In the proposed ultimate system, these categories would be used as backup material when unusual troubles develop which have not been included in the FPJPA for TS. Pictorials with location grids also should be available as backup informational materials.*

Traditional TO Categories Not Included in the SIMS or FPJPA Concepts

Table 4 (page 37) indicates three additional categories of TO data—namely aircraft wiring diagrams, illustrated parts breakdown, and preservation, shipping and storage information. Aircraft wiring diagrams will be required by high level maintenance technicians as part of the recommended modified TO system. None of the new categories of data in the modified TO system cover all of this function. If and when FPJPA for TS are added to the recommended modified TO system, aircraft wiring diagrams still will be required as backup. Most of the illustrations found in the IPB will be found in some form distributed throughout Class A Procedures (FPJPA) described previously. All levels of technicians using the current TO system have a requirement for this category of information. In addition, supply and transportation specialists make extensive use of this category. Even if FPJPA were provided for the maintenance technician, this category would be valuable for the highly trained backup maintenance technicians. The preservation, shipping and storage information category is used by some maintenance technicians and is vital to the work of supply and transportation specialists. The high level maintenance technician must make use of these categories in his communications with supply and transportation people. Concerning the technical needs of supply and transportation specialists, no indepth study has been made concerning the actual data requirements of these users. It is highly possible that these categories of data could be improved for the use of these specialists.

Recommendation D. *The traditional TO categories, wiring diagrams, preservation, shipping, and storage information; and illustrated parts breakdown should be retained in the TO system.*

Recommendation E. *An indepth study of the data needs of the supply and transportation specialists should be given consideration. This study should start with a task identification and analyses of the jobs of these specialists.*

The Optimum Trade-Off Between Technical Data and Training

The two primary objectives of the AFHRL research program in FPJPA have been the improvement of maintenance effectiveness and the reduction of training time. The implementation of recommendations A through C should help accomplish the first objective. *One outcome of the application of the three above recommendations to a TO system would be to increase the utilization of first enlistment 3 and 5 level airmen by a reduction in on-the-job training (OJT) time.* Such an outcome could be expected based on the findings of the HumRRO project FORECAST (21 and 22), the Air Force project PIMO (20), and Air Force Human Resources Laboratory work (1 and 2).

But to make any substantial reduction in formal training with the current Air Force personnel structure, the TS area of maintenance jobs must be greatly simplified. It is hypothesized that the addition of FPJPA for TS would provide the necessary simplification of TS tasks for greatly reducing formal training time. If successful, this would achieve the second objective of the AFHRL research program.

Hypotheses Regarding Further Reductions in Training Time

In addition to the above referenced technical data research, there are a large number of research projects reported in the literature concerning job oriented training and performance testing (Figure 2). *The combined results of the many completed research efforts concerning job oriented training have proven the effectiveness of this training concept conclusively.* An extensive and indepth study of these training efforts has resulted in hypotheses as to the further effect of a combined application of the job oriented training and FPJPA technologies. Simply stated these hypotheses are:

The purpose of this figure is to identify the types of controlled studies supporting these hypotheses, to give the general flavor of their results and to direct the interested reader to available summaries and lists of references on job oriented training, technical data, and performance measurement.

The armed services have conducted at least 10 controlled studies concerning the effectiveness of job oriented training programs for maintenance. The experimental job oriented training programs developed for these studies have been aimed at several types of job situations. Some have been structured to train new military enlisted personnel to perform maintenance jobs involving a number of hardware systems. Other programs were aimed at existing single system jobs. For both these types of programs, the existing job situations were accepted without change. For at least two other studies, the job situations were simplified for the experimental subjects by modified information or directions for performing job tasks and the job oriented training program for each was developed with the objective of training the subjects to perform the tasks of the simplified job.

The effectiveness of each of these 10 experimental job oriented training programs was compared under controlled conditions with the existing theory centered training programs used to train similar personnel. A summary of most of these studies together with a list of reports was made by Foley (6) in 1967. Further information concerning the more recent studies can be obtained from reports by Shriver et al., (22 and 23), Elliott and Joyce (2), Chalupsky and Kopf (3), Pieper et al., (19), Pickering and Anderson (18), Van Matre and Steinemann (26), Steineman and Hooprich (24), and Steineman et al., (25).

An indepth review of all these studies indicates that: (a) job oriented training subjects could perform the tasks of their jobs with much less on-the-job-training (OJT) than the control subjects, (b) medium and some low aptitude subjects were more successful in job oriented training programs than in traditional training programs, (c) job oriented training courses were shorter than conventional courses, and (d) when the jobs were modified with improved job instructions and information, the job oriented training was even shorter.

An indirect source of insight as to the questionable effectiveness of theory-based maintenance training programs is found in research on performance measurement. The student measurement programs in all theory-based training programs are heavily weighted with paper-and-pencil tests of theory and job knowledge. A student usually learns well those things on which he is tested. Foley's summary (4) of the available performance measurement research literature indicates that the *relationship* between the test subjects' ability to actually perform the tasks of maintenance jobs and their scores obtained on theory or job knowledge tests is very low. Likewise, the correlation is low between school marks and measures of job performance. A strong inference can be drawn from these. The only way most personnel learn to perform job tasks is by practicing those job tasks properly. Learning job tasks by practice is what job oriented training is all about.

Figure 2. **Research efforts supporting the FPJPA/Job oriented training trade off hypothese.**

1. Most, but not all, maintenance jobs can be greatly simplified and modified by applying the technology of FPJPA to all the maintenance tasks of the job.

2. The formal training time of the first enlistment personnel to be assigned to these simplified jobs can be greatly reduced by applying job oriented training technology, that is, teach the new airmen how to do the tasks of his job when he uses FPJPA.

3. Medium, as well as high, aptitude personnel, as identified by the Airman Qualifying Examination (AQE), can be trained successfully by using job oriented training technology.

4. The new airmen so trained will be effective very soon after their first job assignment with little or no OJT.

5. An airman so trained and experienced in performing maintenance tasks on one or more equipments or systems will be able to quickly transfer to the maintenance of similar equipments or systems provided these unfamiliar equipments or systems also are supported by FPJPA.

Estimated Gains from the FPJPA/Job-Oriented Training Tradeoffs

Column 10 has been included in Table 4 (page 37) to give a more detailed *estimate* of the increased maintenance efficiency to be expected *if these hypotheses prove to be true*. In the writer's opinion, a synthesis of the results of completed job performance aids research coupled with the results of the research outlined in Figure 2 indicates that the probability of each of these hypotheses being true is extremely high. The purpose of the following discussion is to present the case for such a research program in terms of the gains to be realized by the Air Force if they are true. In other words, an effort will be made to identify potential gains and to argue that these potential gains are so great that the necessary advanced development studies concerning these hypotheses are worthy of support and funding by the Air Force especially in these austere times. The three recommendations that follow this discussion *ask only* that these hypotheses and projections be tested by controlled procedures on a limited number of Air Force maintenance jobs to determine their validity.

Gains for First Enlistment Maintenance Personnel. Many of the current initial training programs are rather lengthy (as long as 48 weeks) and are *general* in nature. Many of these programs do not give the new airmen sufficient opportunity to obtain "hands on" practice on the tasks of his job. (One of the reasons for this situation is that many maintenance AFSC are responsible for the maintaining of so many different equipments that it is impossible to provide indepth training on all of them and still provide the theory background that many people feel is an overriding requirement). As a result, each airman learns the precise maintenance tasks of the equipment to which he is assigned during OJT. One result of the extensive time devoted to military training, formal technical training, OJT, transfers, and retraining after transfer is that many first enlistment maintenance technicians may be effective workers for only one year during their first four-year enlistment.

The cost to the Air Force of maintenance airmen's first enlistment is estimated to be at least $35,000. The re-enlistment rates in some critical maintenance career fields have been as low as *11 percent*. *If* the initial training time of the first term airmen could be greatly reduced, and *if* by the use of FPJPA, these airmen could be made effective workers immediately after training, it is hypothesized that this effective work period could be extended from approximately *one year* to *two and a half years*. The current cost to the Air Force for the current one man-year of maintenance labor therefore is approximately $35,000. Assuming the $35,000 to be a constant, and assuming the extension of the work period to two and a half years, the cost of a maintenance man-year would be reduced to $14,000 or a savings of $21,000 per man-year.

Column 9 of Table 4 (page 37) indicates that there are approximately 76,000 maintenance personnel in their first enlistment. If this savings could be applied to one-half this number, it would result in an annual $800 million maintenance cost reduction. If applied to only 10% of the maintenance work force, an annual savings of $160 million would result.

If FPJPA were injected into the system, it is estimated that these airmen would be able to perform non-TS tasks and TS (reasonably well at the 3 level and fully effective at the 5 level) on the systems for which they will have been trained. These degrees of effectiveness are indicated in column 10 of Table 4 (page 37). (They probably would also be effective on any other system provided FPJPA were available for

the other systems). Column 10 also reflects the assumption that most of these first enlistment airmen *would not* be able to isolate unusual troubles using MDC, keyed schematics, and keyed information. This would be a very small price to pay for their added effective time on the job during their first enlistment–especially since a backup capability would be available in personnel in their second enlistment or beyond.

The envisioned training programs for first enlistment airmen would be relatively short, approximately 25 percent of the current course length and these programs would be equipment specific. These courses and the FPJPA should be developed on the basis of a common task identification and analyses in which the trade-offs between content of training and the content of the FPJPA would be worked out in detail. (It is possible that there could be fewer such courses than equipments in the field provided *similar* FPJPA with similar training trade-offs would be available for all equipments to be maintained by graduates in the field. This is one of the hypotheses to be tested).

Second Enlistment Maintenance Personnel. Those maintenance technicians who wished to re-enlist and whom the Air Force wished to retain would be given broad-based technical training at the beginnings of their second enlistment. Such broad-based training would probably be far more effective at the beginning of the second enlistment than at the beginning of the first enlistment. By this time, each technician would have developed a real world frame of reference in maintenance upon which to relate his technical training. The content and structure of such broad-based training programs should be items for special study. In the writer's opinion, to be most effective for maximum transfer, these programs should be developed to make full use of the airman's already developed frame of reference and to reflect modern job oriented course development technology. Since there would be fewer men to train and since there would be a much greater probability of holding these men after their second enlistment, the Air Force could afford to make this second enlistment training more comprehensive than the current first enlistment training. The *performance* standards for these second enlistment courses should be high in terms of demonstrated ability to perform a large variety of job tasks. Those not successfully completing such training could be given the option of an honorable discharge or completing their enlistment using FPJPA.

FPJPA also would be effective with second enlistment personnel, but second enlistment personnel completing advanced technical training would have the added capability of using MDC, keyed schematics, and keyed information as well as other categories of technical data listed to solve unusual maintenance problems. The author is of the opinion that such a modified personnel and training structure would produce a larger number of technicians who could effectively isolate difficult troubles than produced under the current structure.

Recommendations for Testing These Hypotheses

As stated above, if the hypotheses proposed for test are valid, the savings to the Air Force would be in the hundreds of millions of dollars. But these hypotheses should not be applied on a large scale until they are given comprehensive and indepth tests (controlled and field) on a more limited scale. Such tests would probably cost the Air Force between $4 million and $5 million spread over a period of three years. But, compared to the potential savings this would be a very minor expenditure. The following three recommendations reflect the requirements for the necessary controlled studies.

Recommendation F. *FPJPA and matching job-oriented training should be developed for both organizational and intermediate levels of maintenance for at least one moderately complex electronic subsystem to ascertain whether first enlistment people of both high and medium aptitude with only limited training can successfully perform maintenance.*

Recommendation G. *FPJPA should be developed for at least two other similar equipments for the same career field to ascertain whether or not personnel receiving the recommendation F type of training and experience can, in fact, do effective maintenance on these new systems with a minimum of equipment orientation.*

Recommendation H. *If the above two recommendations are tried and are successful, develop FPJPA for all the systems maintained by this one career field. Later other career fields should be completely converted to the modified TO/training system recommended in this report.*

An advanced development plan was prepared in 1967 and was approved in 1968 providing for recommendations E, F, and G. This plan was later reduced to recommendations E and F. Although this plan was approved and some funds were programmed for its accomplishment, insufficient funds were obligated to accomplish its intent. As a result, the current FPJPA advanced development effort, which is scheduled for completion in June 1976, is evaluating only the effects of FPJPA for TS on maintenance.

IV. PROPOSED MODIFICATIONS TO THE AIR FORCE TECHNICAL ORDER, TRAINING AND PERSONNEL SYSTEMS

This section presents suggested changes to the Air Force TO, training and personnel systems, which result from synthesizing the materials presented and discussed in Sections II and III. The first result of these syntheses are proposed modifications to the Air Force TO system which should result in improved Air Force maintenance as well as greatly reduced maintenance costs. These proposed TO modifications are followed by the results of further syntheses concerning maintenance personnel and their training. The proposed modifications to the Air Force training and personnel systems should further reduce maintenance costs by the reduction in personnel costs.

Proposed Technical Order Categories

Column 8 of Table 4 (page 37) identifies the categories of data which would *ultimately* be required for a *complete* implementation of the *advanced technical order technology*. The categories include:

1. FPJPA for non-TS tasks.
2. MDC with pictorial locators.
3. Keyed schematics.
4. Keyed information.
5. Pictorials with locator grids.
6. Aircraft wiring diagrams.
7. Illustrated Parts Breakdowns (IPB).
8. Preservation, Shipping and Storage Information.
9. FPJPA for TS tasks.

As far as categories go, such an implementation only calls for a modification of the existing technical order system (that is, the substitution of improved categories for existing categories) and the addition of a new category of data, FPJPA for TS. The current state of the technology supports the immediate implementation of all the modified categories except FPJPA for TS. However, the implementation of the FPJPA for TS should wait until the current AFHRL advanced development Project 1194, Evaluation of Fully Proceduralized Troubleshooting Aids, is completed. The completion of this project is schedulted for June 1976.

The proposed modifications to the current TO system are discussed as follows.

1. The retention of three currently existing categories of information without change; namely, the aircraft wiring diagrams, the illustrated parts breakdown, and preservation, shipping and storage information.

2. The minor modification of an existing category by the addition of grids to pictorial location diagrams.

3. The substitution of FPJPA procedures (similar to those found in job guide manuals) for current TO procedures for all non-TS tasks. These procedures would include all checkout procedures; align, adjust and calibrate procedures; and remove, replace and repair procedures. (Table 4, page 37, shows this proposal simply as the substitution of Type A procedures for Type C procedures.)

4. The substitution of a more sophisticated category of gross troubleshooting directions (maintenance dependency charts with pictorial locations) for two existing categories of troubleshooting directions (sympton-cause charts and logic diagrams). The MDC with pictorial locators are represented in Column 4 of Table 4 as Type A MDC.

5. The substitution of keyed schematics (MIL-M-38799) for traditional schematics.

6. The further substitution of MDC and keyed schematics for three other traditional categories – flow diagrams, normal readings and/or tolerance charts, and block diagrams.

7. The substitution of the keyed information category for the traditional theory of operation category.

The above recommended mix of categories should result in a *modified* TO system which will: (a) greatly improve the data support for maintenance technicians, and (b) still retain its present usefulness for other users of the system. The proposed *modified* TO system would have only *nine* categories whereas the current TO system requires 11 categories. (Twelve categories are shown in Column 3 of Table 4, page 37, but a TO system usually includes only one of the directions for TS categories.)

Benefits from Proposed Modifications for Training and Personnel Systems

Any reductions in maintenance personnel and training costs, and any improvements in the quality and efficiency of the performance of maintenance, will result in reduced life cycle costs of hardware systems. Maximum cost benefits for maintenance, training and personnel will be effected only after the proposed integrated mix of improved TO categories and job-oriented training are fully implemented. Less impressive cost benefits can be obtained by more modest implementations. The discussions that follow consider the benefits to be expected from a full implementation of such a mix as well as from some partial implementations.

Results Expected from a Full Implementation of Recommended TO Categories and Job-Oriented Training

The types of job aids and training which would probably result in maximum cost effectiveness for maintenance are briefly summarized in Columns 1, 2, and 3 of Table 3. Column 4 lists some of the training gains that could be expected. Column 5 lists some of the maintenance gains that could be expected. Most of the maintenance and training gains summarized in Table 3 have been discussed in Sections II and III. Two important personnel gains should be emphasized here: (a) The net result, of shorter first enlistment training and the resulting longer time on the job, would be fewer people in the Air Force; and (b) the potential for the reduction of "build up" time in cases of national emergencies is, in the opinion of the author, an extremely important personnel gain to be expected.

Rapid "Build Up" Potential. In regard to this rapid "build up" potential, the Air Force has placed a great deal of reliance on training people in advance of such emergencies. Even in "normal" peace times, the Air Force has experienced difficulty in fielding a sufficient number of proficient technicians to adequately maintain its hardware. The "active duty" time of most Air Force hardware systems and subsystems can usually be measured in decades, whereas the active duty time of maintenance personnel on such hardware has been relatively very short – in some cases as short as one year or less. The result is that, at any one time, the Air Force has a rather small cadre of proficient maintenance personnel upon which to rely in case of national emergency.

Relying on people with previous experience and/or training has not proven too successful for emergencies. Many times such people are not available when their services are required or it they are available, they have lost their job proficiency due to lack of use. And in many cases their services are required on hardware other than that upon which they were experienced or trained. A possible result could be that a much larger number of hardware could be available for action than proficient maintenance technicians for keeping them in operation. But such are the hazards of "storing" job proficiency in people for possible future use.

FPJPA provide a means for the permanent storage of the necessary guidance and cues for the successful job performance. They would not be subject to human forgetfulness. They would be available at the time of need for both inexperienced personnel as well as for personnel with past experience who have lost their proficiency. But such FPJPA must be ready for use before the emergency arrives.

Table 3. Chart Displaying Proposed Maintenance TO Categories, Types of Training, and Expected Gains from Full Implementation

(1) Enlistment	(2) Categories of Job Aids	(3) Type of Training	(4) Training Gains Expected[a]	(5) Maintenance Gains Expected[a]
First	1 FPJPA (Non-TS Tasks) 2 FPJPA (TS Tasks)	Short job-oriented training with supervised practice on 1 Use of FPJPA 2 Use of Hand Tools. 3 Use of Test Equipment 4 Safety practices	1 Length of initial training reduced by at least 75 percent. 2 Resulting in fewer people requiring training. Average, as well as, high aptitudes could be trained. 4 Shorter personnel build up time required for national emergencies. 5 Reduction in initial OJT and job cross training. 6 Reduction or elimination of formal special and supplemental training.	1 Such personnel job ready at end of formal training. 2 More effective performance at non-TS tasks. 3 More effective performance of TS Tasks—estimate such personnel can isolate 95 percent of possible troubles. 4 More months on job due to shorter training time, thus fewer personnel in the Air Force. 5 Minimum of cross training to unfamiliar equipments (provided FPJPA available on unfamiliar equipments). 6 More effective utilization of maintenance personnel during peck and/or emergency. 7 Fewer unsolved maintenance problems referred to depot ∴ reduction in depot maintenance. 8 Fewer space parts consumed. 9 Less paper work generated. 10 Less secondary damage from unnecessary maintenance actions.
Second and beyond	1 FPJPA (Non-TS Tasks) 2 FPJPA (Most TS Tasks) For Unusual TS Tasks: 3 MDC with pictorial locators 4 Keyed schematics 5 Keyed information 6 Pictorials with locators grids. 7 Aircraft wiring diagrams. 8 IPB 9 Preservation, Shipping and Storage Info.	Broadbased training developing ability for solving and correcting unusual maintenance problems	1 More effective training for backup personnel. 2 Fewer people requiring long, broadbased training.	1 A larger number of highly effective backup maintenance personnel for performing unusual and difficult maintenance tasks. 2 Fewer unsolved maintenance problems referred to depot ∴ reduction in depot maintenance.

[a]The projected gains are based on projections of hard data outlined in Figures 1 and 2.

Recommendation I. *An indepth study should be made of the potential of FPJPA for the rapid buildup of forces in cases of national emergency.*

Other Expected Gains. Some gains can be expected that were not discussed previously. One of the implementation problems experienced during PIMO project and during the Vietnamization project was getting experienced personnel to use the FPJPA while performing tasks. In fact, there has been a general Air Force problem of getting technicians to use their TO while performing tasks. One of the outcomes to combining job-oriented training and FPJPA for first enlistment airmen would be to force the use of FPJPA while performing maintenance tasks; at least for the first few performances of each task. Because, that is the way they will be taught to do it; and it will be the only way they will be able to accomplish the tasks.

Another gain listed in Column 5 concerning a minimum of cross training required for unfamiliar equipments has several important training implications. This would, as discussed, reduce initial OJT and costly on-the-job cross-training to unfamiliar equipments. *In addition, it would eliminate the requirement for formal special training and supplemental training, provided that FPJPA were developed for both TS and non-TS tasks for their equipments.* A large portion of technical training expenditures are for special and supplemental training. Any reduction in such training would result in substantial monetary savings to the Air Force.

Investment Required. It should be noted that all of these expected gains will require increases in current expenditures for the development of the necessary improved TO categories. Also, the cost per week of job-oriented training is greater than for theory-based training. Job-oriented training requires more equipment and/or trainers for hands on practice and a greater instructor to student ratio. Although these increased costs are minor when compared to the expected gains, they are investments that must be made several years before all the expected gains can be realized.

Results Expected from a Partial Implementation of the Proposed TO/Job-Oriented Training System

A full implementation of the proposed TO categories without modifying training would probably improve maintenance provided maintenance technicians would use the FPJPA while performing their maintenance tasks. Some impressive improvements in maintenance and savings in training can be made by applying job oriented training to maintenance jobs of limited scope as was done in the Air Force Learner Centered Instruction (LCI) Project (19). But to obtain all of the gains outlined in Table 3, there must be a quality integration of both improved TO categories and job oriented training. Because the field test of FPJPA for TS will not be completed until at least June 1976 (Figure 1), a full implementation is not possible at this time. As discussed previously, the formats of all of the proposed TO categories outlined previously, with the exception of FPJPA for TS, are accepted Air Force maintenance data and their systematic implementation has been recommended. The following paragraphs concern the gains to be expected from such an implementation with and without personnel and training modifications.

Gains from Implementation of all Proposed Categories of Data Except for Troubleshooting with Current Personnel System. As discussed in Section III, such an implementation would provide the capability for first enlistment airmen to perform non-TS tasks proficiently on any system related to their AFSC with a minimum of OJT. First enlistment personnel could, thus become productive workers almost immediately upon assignment to a maintenance unit. But most TS tasks would require highly trained and experienced personnel. However, these experienced personnel would be able to perform TS tasks more effectively with MDC based aids including keyed schematics and information, thus reducing spare parts consumption. Under these conditions, the MDC based aids would be the primary troubleshooting data. Such a TO implementation would not conflict with a later implementation of FPJPA for TS, since the MDC based TS aids would then be required to support experienced backup personnel. Better utilization could be made of maintenance personnel since all personnel in related career fields could perform non-TS tasks for which FPJPA were available. Since all personnel must theoretically be available for performing TS tasks during their first enlistments, no reduction in formal training could be effected based on the field use of FPJPA for only non-TS tasks.

Gains from a Modified Personnel System. Sizeable training savings could be effected by restructuring maintenance career fields so that each career field would have designated non-troubleshooters and troubleshooters. The non-troubleshooters could be first enlistment personnel who have been given a short

job-oriented training with supervised practice in use of FPJPA, hand tools and test equipment. The designated troubleshooters would be given broad-based training. In the opinion of the author, most second enlistment personnel could be placed in this category. However, a great many first enlistment personnel would also have to be placed in this category to obtain sufficient troubleshooters. This would probably cause morale problems among first enlistment personnel due to differences in training and assignment. The training savings would not be of the same magnitude that could be effected by the implementation of FPJPA for TS.

Troubleshooting (TS) – The Most Critical Maintenance Activity. In considering the relative effectiveness of the various categories of data coupled with various possible modifications in the personnel and training systems, it is important to emphasize that trouble identification is the most difficult and expensive maintenance activity. The availability of FPJPA for non-TS tasks will, of course, improve the performance of such tasks. They will do little to improve the performance of TS. The limited amount of available hard data concerning the correction of troubles indicate that the identification of troubles is in general being performed very inefficiently. Many good components are removed and replaced before the faulty components are identified, resulting in excessive consumption of spare parts. Even though Air Force maintenance training is long and expensive, the present system produces relatively few good troubleshooters. Yet, few if any effective actions have been taken to increase TS efficiency (7).

The MDC based TS aids provide a proven technology for an improvement in TS efficiency. FPJPA technology may offer even greater cost savings. Job-oriented training if properly applied can also increase TS efficiency. As outlined previously, all of these technologies are projected for use in an optimum system. Considering the current high cost of TS, these technologies should have extremely high implementation priorities.

Currently offered alternatives to MDC based TS aids and FPJPA for TS include symptom-cause charts and logic trees. Symptom-cause charts have a poor history for TS effectiveness, and the effectiveness of so called logic trees for TS is unproven. The current weaknesses of logic trees probably stem from their lack of content consistency from development to development. Using current specifications, there is no way of insuring the quality and completeness of their content. Symptom-cause charts and logic trees have been offered as less costly than MDC and FPJPA for TS. In the opinion of the author, both could be developed into effective aids. But to be consistently effective, the development of such aids would require the same type of controls required for the development of effective MDC based aids and FPJPA. Such action would of course increase their initial costs. Such aids so developed might have similar potential as MDC based aids for improving the troubleshooting effectiveness of highly trained, experienced maintenance personnel. They would not be effective with novice or apprentice maintenance personnel.

V. IMPLEMENTATION CONSIDERATIONS

The full implementation of the proposed categories of TO materials together with the proposed supporting training outlined in Table 3 will require changes in the Air Force TO, personnel, training and maintenance systems. In considering implementation, the facts should be emphasized that the technologies for all the recommended JPA categories with the exception of FPJPA for TS are officially accepted categories and that FPJPA for TS are in the final advanced development stage. The implementation of FPJPA for TS should depend on the outcome of this advanced development program. The technology of job-oriented training has been successfully demonstrated many times and these successes have been well documented (6). Although demonstrated on a limited scale (17), the proposal for combining of the FPJPA and job oriented training has never received a controlled evaluation. The various recommendations for implementation of JPA and further research and development presented in this report reflect these differences in confidence levels.

It is of course impossible to anticipate all of the problems and obstacles concerning these recommendations. However, the author has been involved in implementation efforts concerning FPJPA for both TS and non-TS tasks and MDC based TS aids for the Vietnamese Air Force, as well as, in efforts concerning development of FPJPA for non-TS tasks for the U.S. Air Force, the Army, and the Navy. He has also been involved in several job-oriented training efforts. The discussions that follow reflect these experiences, as well as his concerns for the tryout and implementation of quality products of the JPA and job-oriented training technologies. These discussions involve the impacts on the Air Force TO, training, personnel and maintenance systems.

The Production of Improved Technical Order Categories

The Air Force and the Navy have already had some experience concerning the contractor development of advanced type JPA including FPJPA for TS and non-TS tasks as well as MDC based TS aids. These developments have surfaced some areas of concern. In addition, the injection of MDC based TS aids, as well as FPJPA for non-TS (job guide manuals) into the Air Force inventory has been extremely slow. The following discussions and recommendations reflect these concerns.

FPJPA Technology Concerned with Content

From a *format point of view* the Air Force has made some progress toward the injection of the recommended categories into the TO system. MIL-M-38800 (15) authorizes a format for FPJPA for non-TS tasks (job guide manuals) for aircraft systems only as indicated in Column 6 of Table 4 (page 37) (Type B procedures). This format looks very much like the FPJPA for non-TS tasks found in AFHRL-TR-73-43(I) (11). MIL-M-38799 (15) authorizes an excellent format for MDC with pictorial locators that look very much like that found in MIL-J-83302. If format alone was the AFHRL technology for improved technical data, the implementation problems would be only those of accelerating what has already been started. But format is only a picture of the final product and it does not control the content required by the technology.

The recommended categories for the modified TO system outlined in Table 3 fall into two rather distinct classes. The first is primarily job oriented; that is, structured as the maintenance job is structured. These aids provide step-by-step directions which the technician is expected to follow precisely. And if he follows these directions precisely, he can expect to accomplish the tasks or parts of tasks for which the aids were developed. They direct the behavior of the technician and the desired course of action is plotted for him in advance. Only the necessary information about the hardware being maintained is provided and such information is structured within the framework of the step-by-step instructions for the tasks. The FPJPA are of this first class.

The second class is primarily equipment oriented; that is, structured as the hardware is structured. Each category of data in this category provides information about some aspect of the hardware. The organization of this information reflects either the physical or operational structure of the hardware. The technician *must* plot his own course of action and either carry the necessary bits of information about the system in his head, for recall as needed, or obtain them by searching his TO information categories. *Traditional examples* of such categories are *schematics* and *theory of operation*. Efforts to improve these categories for use by technicians have resulted in blocked schematics, keyed schematics, blocked information and keyed information. The improved categories are still equipment-oriented.

The MDC contain features of both classes. The checkout procedures included in these charts are of the first class. They are job oriented in that they tell the maintenance men what to do to find the set of dependencies containing the fault. But the sets of dependencies provided by the charts are of the second class. They provide information about the system. The maintenance man must plot his own course of action (selecting the appropriate information from keyed schematics and keyed theory of operation information) to locate the actual faulty component. MDC require their own special analyses in addition to those required for FPJPA for non-TS tasks.

Blue Print Required. To *ensure* that all of these and other aspects of the technology are found in the FPJPA for non-TS tasks and TS tasks and in MDC for TS, a system of task identification and analysis of the identified tasks is provided in the technology. The latest revision of this system appears in AFHRL-TR-73-43 (I, II and III) (11, 12, and 13). The special analyses required for MDC appear in MIL-J-83302 (14). The structured task identification and analysis system results in a number of deliverable subproducts which become criteria for the contractor, his data craftsmen and the Air Force data managers.

Equipment-Oriented TO Categories and Task Identification and Analysis. Most of the early TO categories were data which were developed for the production of the hardware. This is true of such categories as schematics, pictorials, block diagrams, normal reading and/or tolerance charts, and aircraft wiring diagrams. In fact, some of the items are planning and development data used in the manufacture of the hardware – the "blue prints" used for manufacture. *A format type of specification is all that is* required

for these categories of data. For example, the completeness and accuracy of a schematic can be determined by comparing its symbolic content with the component content and electrical structure of the actual hardware.

The theory of operation category, which was demanded by the users of hardware, is an exception. It is an attempt to explain the theory behind the design, using a word description of how and why the hardware works. The quality of this category varies greatly from system to system. It has always been very difficult to control its level of detail. To control the content and quality of this type of writing would be as difficult an endeavor as for a teacher trying to control the quality of college themes, or a laboratory attempting to control the quality and content of contractor technical reports. About all that can be controlled is the reading level of this type of material.

In the writer's opinion, this fact that most traditional categories are equipment oriented and require only a format type specification for their development and control is a major factor in the current resistance to task identification and analysis for FPJPA and MDC. The mental set of most technical writers and data managers is naturally equipment oriented. When they look at FPJPA and MDC, they see the difference in these data from other data as a simple matter of format. It is difficult for them to understand that format, in this case, is only secondary and that the precise maintenance job considerations are primary. They do not understand that the job structure is the foundation of the new technology and that job structure is not in the format alone. They do not understand that to control the content and level of detail of the FPJPA and MDC (without the subproducts of task identification and analysis) will be an even more elusive task than to control the content and level of detail in the theory of operation category.

The Specification of Task Identification and Analyses. To ensure the necessary task identification and analyses subproducts they must be *specified*. Such a specification can be obtained by integrating the requirement for these subproducts into the FPJPA specification as has been done in MIL-J-83302, AFHRL-TR-71-53(I) and AFHRL-TR-73-43(I). This approach assumed that the same contractor would develop both the subproducts for task identification and analysis and the resulting FPJPA. There may be distinct advantages for having a separate specification for the subproducts of task identification and *parts* of the necessary task analyses. A two-step procurement procedure could then be used. The first step would be to develop the necessary subproducts of task identification and analyses which would quantify the size of the FPJPA production job to be accomplished by the second procurement step. The task identification and analyses specification would be used as the basis for the first step. The specification used for the second step would specify format and some task analyses subproducts not included in the first specification. Such a division of current model specifications (such as AFHRL-TR-73-43(I)) would require very careful study. The subproducts of the first specification would of course be referenced in the second specification as criteria for the content of the FPJPA system being developed.

Recommended Action

Recommendation J. *The official specification for the production of FPJPA for non-TS tasks and for the production of MDC (MIL-M-38800 and MIL-M-38799) should be modified to require the production and use of subproducts of task identification and analyses such as is found in AFHRL-TR-73-43(I). The specifications for MDC (MIL-M-38799) should reflect the special additional subproducts of analysis for MDC found in MIL-J-83302. FPJPA technology should be applied to all non-TS tasks for both organizational and intermediate maintenance – not just to organizational maintenance for aircraft.*

Recommendation K. *A careful study should be made concerning the advantages and disadvantages of developing separate specification for task identification and part of the required analyses of the identified tasks and withdrawing these requirements from specifications for FPJPA and MDC. Such a division may have advantages for two-step procurements of such data.*

Quality Control Use of Subproducts in FPJPA Production

The production of quality FPJPA requires the production of quality subproducts of task identification and analyses and the use of these subproducts as criteria during the development of the FPJPA. The quality of subproducts cannot be ensured if they are not adequately evaluated and accepted by knowledgeable representatives of the procuring agency. The procuring agency must also have the capability

for continually evaluating the production of FPJPA using the subproducts as criteria. The implementation of the FPJPA and MDC technology requires that industry develop the personnel capability for producing the subproducts of task identification and analyses and the capability for developing FPJPA based on these subproducts. The procuring agencies must develop the capabilities for evaluating and accepting the subproducts and for effectively monitoring the FPJPA and MDC during their development. Once the procuring agencies develop their management and technical capability, and industry understands what the Air Force wants, industry will develop the necessary capability. In fact, at least a few contractors already have taken steps in this direction.

The Air Force cannot afford to develop such management and technical personnel for one project and start all over again for the next project. For example, the Helicopter Programs Office of the Aeronautical Systems Division at Wright-Patterson AFB, Ohio developed considerable expertise in the procurement and management of FPJPA and MDC using subproducts. This experience and expertise was gained during the procurement of FPJPA for ten systems for the Vietnamization effort from 1969 through 1972. Upon completion of these efforts, the members of this team were reassigned to other duties. Since that time, FPJPA have been developed by other Air Force units for the C-141, the B-52, KC-135 and the F-106. Each of these efforts were started under the guidance of Air Force procurement and technical data management personnel with no previous FPJPA experience.

Recommendation L. *An indepth study should be made to ascertain the most effective and efficient means for developing and retaining the Air Force expertise for the purchase and management of technical data developed in accordance with the FPJPA technology. This study should consider the number and types of systems for which FPJPA are to be developed.*

Experience has indicated that the development of subproducts and their use as criteria during the development of FPJPA is not a substitute for the hands on validation and verification of the final FPJPA. The subproducts also can be used as added criteria for completeness during validation and verification. If the subproducts have been applied properly during the development of the FPJPA, the number of data changes and corrections to be made after validation and verification should be small. In addition, the need for some important changes can be identified early in the developmental stage before their cost becomes prohibitive.

Implementation and Implementation Policy

From a format point of view, FPJPA for non-TS aids and MDC based TS aids have been accepted as official Air Force maintenance data since 1969 and 1967, respectively. But these data have not officially replaced any of the other existing categories of data which this report recommends. To date, the injection of FPJPA for non-TS tasks has been very slow and the number of MDC-based TS applications has been extremely small. The Air Force PIMO project, which field tested and recommended such a mix of aids on the C-141, was completed in May 1969 (20). In April 1975, FPJPA for non-TS tasks and untested logic trees for TS were delivered to the Air Force in reproducible form. After being printed by the Air Force, they were introduced into the C-141 maintenance units starting in September 1975. Similar aids are now being developed for the B-52, the KC-135 and the F-106, but without the benefit of the subproducts of task identification and analyses. Regarding new systems, FPJPA for non-TS tasks are being developed for F-5E, A-10, F-16, and B-1. Some subproducts are being developed for the F-16. (The author is of the opinion that the logic trees will improve the TS performance of experienced personnel. They will not replace the requirement for schematics and theory of operation information for such personnel. The MDC-based TS aids may be more effective than logic trees for this purpose).

For the Air Force to realize the benefits projected in this report, a much faster implementation program is required. An effective implementation will require high level, positive, aggressive action supported by the necessary funds.

Recommendation M. *An effective implementation of this proposed technical data program will require high level, positive, aggressive action supported by the necessary funds.*

Such aggressive action should include an official policy statement concerning the approved mix of categories of maintenance, and requiring that such a mix be applied to all new hardware systems and requiring a priority listing of existing hardware systems for which such data should be developed.

Recommendation N. *An official policy statement should be issued which will state that the approved mix of categories of data for organizational and intermediate maintenance shall be:*

1. *FPJPA for non-TS tasks.*
2. *MDC with pictorial locators.*
3. *Keyed schematics.*
4. *Keyed information.*
5. *Pictorials with locator grids.*
6. *Aircraft wiring diagrams.*
7. *Illustrated parts breakdowns (IPB).*
8. *Preservation, shipping and storage information.*

New Systems. The development of such data would no doubt decrease the life cycle cost of new systems. However, this cost effectiveness is not reflected in system development and procurement costs. FPJPA for non-TS tasks do cost more money initially. The addition of a requirement for the other categories, especially the MDC, would further raise the development and procurement costs. It has been suggested that for at least one or two new systems, special development money be used which would *not* be charged to the systems development cost. This seems to be the only feasible answer to the money problem. The new technical order system is a new systems development in itself and its development should be treated as such.

Recommendation O. *The official policy statement should include the requirement that the maintenance data for all new systems will include the approved mix of categories.*

Existing Systems. The maintenance savings to be gained by developing the recommended modified TO system for existing weapons systems should be exploited. The greatest potential maintenance savings for the least expenditure of TO development money should be a prime consideration in the selection of weapons systems for TO modification. A mathematical model should be developed which would provide systematic consideration of the many factors involved in such a selection, such as, the age of a system and its life expectancy, the number of replaceable units at the organizational and intermediate levels of maintenance, the number of systems in the Air Force inventory, the spare parts consumption in terms of cost, and the number of maintenance people to be affected by the modification. In addition, the mathematical model should predict the cost of such modifications. Data concerning each major system in the inventory should be studied using these models. An ordered list of systems should be prepared based on these cost and savings figures. As money becomes available, systems high on this list should be selected for conversion. Such a study would, also, identify obsolete high maintenance cost systems which should be retired from the Air Force inventory.

Recommendation P. *A priority listing of existing weapons systems should be established, for which advanced JPA should be prepared. This priority list should be established using a systematic procedure which considers many cost effectiveness factors.*

Impact of FPJPA on Personnel and Training Systems

If the promising hypotheses concerning FPJPA for TS prove to be valid, it will be possible to exploit the potential formal training savings suggested for first enlistment airmen. For maximum benefits, an in-depth study must be made of the *impact* of the combination of FPJPA and job-oriented training on the maintenance portion of Air Force personnel and training system. Such a study should include an in-depth analysis of the equipment content of each maintenance AFSC as to its numbers of equipments, as well as to the design concept, the maintenance concept, and the complexity of each equipment. The distributions by commands of equipments and their associated maintenance technicians should be ascertained. This should result in a picture of how the personnel in each maintenance AFSC are utilized. The study should also

identify the hardware systems or combinations of hardware systems for which the new TO technology should be applied to benefit the greatest number of technicians. This would also identify pools of personnel for which job-oriented training combined with FPJPA would result in the greatest pay off. Such an analysis would identify many administrative problems that would result from the implementation of the new TO technology. Even if FPJPA were never added to the TO system, such a study would provide very valuable information for a long overdue restructure of Air Force maintenance AFSC.

Recommendation Q. *An indepth study should be made of the impact on the Air Force personnel and training system of the proposed TO system (including FPJPA for TS) together with job-oriented training.*

VI. SUMMARY AND CONCLUSIONS

1. It is envisioned that a full integration of FPJPA and other advanced type of technical data categories into the TO system to meet the needs of all users will ultimately result in the following categories of data for both *the organizational and intermediate levels* of maintenance:

a. FPJPA for non-troubleshooting tasks (currently called job guide manuals).

b. FPJPA for troubleshooting tasks.

c. MDC with pictorial locators.

d. Keyed schematics.

e. Keyed information.

f. Pictorials with locator grids.

g. Aircraft wiring diagrams.

h. Illustrated parts breakdowns.

i. Preservation, shipping and storage information.

2. The development and proper utilization of a technical order system containing all of the above categories should greatly improve the quality of maintenance and would greatly reduce on-the-job training. This would make personnel newly assigned to maintenance units effective on non-troubleshooting tasks almost immediately upon assignment.

3. Based on the analyses of this report none of the above actions for the improvement of technical data for the maintenance technicians would adversely affect the technical data system for other users. These users include supply and transportation specialists, operators, design and service engineers, curriculum planners, trainers (instructors), trainees, and administrators.

4. The illustrated parts breakdowns and the preservation, shipping and storage information are very important categories of technical data for supply and transportation specialists. No indepth study has been made concerning the actual data requirements of these users. It is highly possible that these categories of data could be improved for the use of these specialists.

5. With the exception of FPJPA for troubleshooting (and pictorials with locator grids) all of the above categories are officially authorized in some fashion as categories of data available to Air Force users. Pictorials without grids are available as a category in current TO. The addition of grids would be a minor change.

6. FPJPA for non-troubleshooting and troubleshooting tasks are job oriented data. With the exception of MDC, the other categories of TO data listed in paragraph 1 are equipment oriented. A large part of the MDC is job oriented, but it does have some equipment oriented aspects.

7. The purely equipment-oriented categories of data require only format specifications for their production and control. But, FPJPA and MDC require the subproducts of job task identification and analyses of the identified tasks for their production and control. The analyses are the bases of the AFHRL technology. The resulting format are of secondary importance. Until the subproducts resulting from these analyses become firm requirements in specifications, the technology has not been fully implemented.

8. The current specifications for FPJPA for non-troubleshooting tasks (MIL-M-38800) and for MDC (MIL-M-38799) do not require them to be based on uniform task identification and analyses procedures. This serious omission in these specifications must be rectified before the substantial gains projected in this report can be realized.

9. The complete implementation of all the categories listed in paragraph 1 (with the exception of FPJPA for troubleshooting) for any system should greatly improve the quality of maintenance on that system, provided the MIL-M-38800 and MIL-M-38799 are modified to require the necessary task identification and analyses subproducts, and these subproducts are used properly in the management of the development of FPJPAs for non-troubleshooting tasks and for MDC. In addition, the amount of on-the-job training required before first enlistment 3 level personnel could be assigned to perform non-troubleshooting tasks would be greatly reduced. These maintenance and training gains would result in a substantial reduction in life cycle costs for a system.

10. A separate specification for subproducts of task identification and a portion of the task analyses subproducts may have advantages for two-step procurements. The first step would be the development of these subproducts which would quantify the magnitude of the maintenance instructions to be developed. The second step would be for the development of the maintenance data prescribed by the subproducts. These subproducts would be withdrawn, but referenced in the specifications for FPJPA and MDC.

11. Although the technology will support FPJPA for non-troubleshooting tasks for all organizational and intermediate level maintenance tasks, MIL-M-38800 authorizes FPJPA for non-troubleshooting tasks for organizational maintenance on aircraft only.

12. Even though permissive format authorizations are now available for the development of FPJPA for non-troubleshooting tasks and for MDC, there is no firm official Air Force policy that these are preferred categories of data. A suggested solution would be an official Air Force statement indicating that the categories listed in paragraph 1 (with exception of FPJPA for troubleshooting) are the authorized categories. If this is not done and if some of the current categories are not withdrawn from the authorized Air Force TO system for maintenance, the Air Force could end up with a "grab bag" of categories which could result in some mixes of data which would be most inadequate.

13. The effective implementation of the TO and job-oriented training proposals of this report will require high level, positive, aggressive action supported by the necessary funds. Such an implementation requires the changes of attitudes and behaviors of too many people for it to come about just because the proposals are sound.

14. The monitorship of the development of the subproducts of task identification and analyses; their evaluation and acceptance; and their proper application during the technical data development require a team of managers and technicians with special skills. Such a team of specialists was developed in the Aeronautical Systems Division at Wright-Patterson AFB during the JPA effort for Vietnamizationn. During that effort, FPJPA for troubleshooting and non-troubleshooting were developed for ten hardware systems, involving three contractors. After this effort was completed the members of this team were assigned other duties and this expertise was lost. This should not be permitted to happen in the future.

15. It is hypothesized that the development of FPJPA for non-troubleshooting and troubleshooting tasks for both organizational and intermediate maintenance could result in greatly reduced training time for the first term enlistee. This would require a very precise consideration of the FPJPA/training trade-offs during their development. The appropriate device for this trade-off is a structured task identification and analysis system. But, the required ingredient for the projected savings in *formal* training, an ingredient which is not now available for official use, is the category of FPJPA for troubleshooting. Trouble identification is the most difficult and expensive maintenance activity. Yet, few if any effective actions have been implemented to increase troubleshooting efficiency.

16. Even though the job-oriented training technology has not been widely adopted by the Air Force, there is overwhelming evidence as to the success of this technology, when properly applied. Most application models have required a large amount of supervised, hands on, equipment practice. Since most maintenance AFSC have such a large number of equipments, hands on practice on all equipments during training is impossible. FPJPA offer a solution to this problem. It is hypothesized that if trainees practiced all key tasks in formal training on one typical equipment using FPJPA, such trainees could perform key tasks on similar equipment after graduation, provided, of course, that FPJPA were available for the similar equipment.

17. FPJPA for troubleshooting and a troubleshooting package made up of MDC, keyed schematics, and keyed information (the MDC package) duplicate each other in a way. But, without the FPJPA for troubleshooting, the training trade-offs for first term airmen could not be realized. But, without the MDC package, the high level technician would not have his necessary backup information. Therefore, both types of data are necessary. If only MDC packages were provided, the Air Force could expect an improvement in troubleshooting efficiency on the part of highly trained and experienced technicians – but no savings in formal training time.

18. If, and when, FPJPA are injected into the Air Force system, they should result in substantial impact on the Air Force personnel and training system. No serious effort is being made to study the impact of the FPJPA for the possible improved efficiency of training and personnel systems. It is hypothesized that hundreds of millions of dollars could be saved by the proper mix of FPJPA and job-oriented training together with the necessary modifications to the personnel systems. Such savings would, of course, be reflected in a further reduction in life cycle costs beyond those indicated in conclusion 9.

19. In addition to the potential for reduction in regular formal training, it is hypothesized that FPJPA technology has potential for greatly reducing the current costly requirements for special and supplementary training.

20. It is hypothesized that FPJPA technology has great potential for the rapid buildup of forces in cases of national emergency provided the FPJPA are available when the emergency arrives.

21. In considering implementation actions for the various proposed categories of data coupled with various proposed modifications of the personnel and training systems, it is important to emphasize that trouble identification is the most difficult and expensive maintenance activity. The availability of FPJPA for non-troubleshooting tasks will, of course, improve the performance of these less difficult and demanding tasks. They will do little to improve the performance of troubleshooting. Even though Air Force maintenance training is long and expensive, the present system produces relatively few good troubleshooters. Yet, few if any effective actions have been taken to increase troubleshooting efficiency.

VII. RECOMMENDATIONS

1. Fully Proceduralized Job Performance Aids (FPJPA) for non-troubleshooting tasks developed on the bases of a structured task identification and analysis system should replace the current step-by-step procedures now found in technical orders. This recommendation applies to both the organizational and intermediate levels of maintenance. (See recommendation A, page 16).

2. After appropriate field tests, FPJPA for troubleshooting should become part of the TO system. It is envisioned that such data would be the primary troubleshooting guidance and would be used by all 3, 5, and 7 level technicians for practically all troubleshooting activities for organizational and intermediate levels of maintenance. (See recommendation B, page 17).

3. Maintenance Dependency Charts (MDC) with pictorial locators as well as keyed schematics and keyed information also should be a part of the TO system. These categories of data are now specified in MIL-M-38799 but without the benefit of uniform task identification and analyses procedures. Until FPJPA for troubleshooting are available these categories of data would serve as the primary troubleshooting data. In the proposed ultimate system, these categories would be used as backup material when unusual troubles develop which have not been included in the FPJPA for troubleshooting. Pictorials with location grids also should be available as backup information materials. (See recommendation C, page 17).

4. The traditional TO categories (preservation, shipping, and storage information, and illustrated parts breakdown) should be retained in the TO system in their current form for the present. (See recommendation D, page 17).

5. The official specifications for the production of FPJPA for non-troubleshooting tasks and for the production of MDC (MIL-M-38800 and MIL-M-38799) should be modified to require the production and use of subproducts of job task identification and analyses of identified tasks such as are found in AFHRL-TR-73-43(I). The specifications for MDC (MIL-M-38799) should reflect the special additional

subproducts of analyses for MDC found in MIL-J-83302. FPJPA technology should be authorized for all non-troubleshooting tasks for both organizational and intermediate maintenance of all hardware systems – not just organizational maintenance for aircraft. (See recommendation J, page 27).

6. A careful study should be made concerning the advantages and disadvantages of developing a separate specification for subproducts of task identification and part of the subproducts of analyses of the identified tasks and withdrawing these requirements from specifications for FPJPA and MDC. Such a division may have advantages for two-step procurement of such data. (See recommendation K, page 27).

7. An effective implementation of this proposed technical data program will require high level, positive, aggressive action supported by the necessary funds. Such an implementation program is recommended. (See recommendation M, page 28).

8. An official policy statement should be issued which indicates that the preferred mix of categories of data for organizational and intermediate levels of maintenance shall include: (a) FPJPA for non-troubleshooting tasks (job guide manuals), (b) MDC with pictorial locators, (c) keyed schematics, (d) keyed information, (e) pictorials with locator grids, (f) aircraft wiring diagrams, (g) illustrated parts breakdowns, and (h) preservation, shipping and storage information. If and when FPJPA for troubleshooting tasks are successfully field tested, this category should be added. In addition, this statement should indicate which current categories of data that should eventually be dropped as authorized categories of data. (See recommendation N, page 29).

9. The official policy statement should include the requirement that the maintenance data for all new systems will include this approved mix of categories. (See recommendation O, page 29).

10. An indepth study should be made to ascertain the most effective and efficient means for developing and retaining the Air Force expertise for the purchase and management of technical data developed in accordance with the FPJPA technology. This study should consider the number and types of systems for which FPJPA are to be developed. (See recommendation L, page 28).

11. A priority listing of existing weapons systems (for which the approved mix of categories are to be developed) should be established. The priority should be established using a systematic procedure which considers many cost effectiveness factors. (See recommendation P, page 29).

12. FPJPA for non-troubleshooting and troubleshooting tasks together with matching job-oriented training should be developed for both organizational and intermediate levels of maintenance for at least one moderately complex electronic subsystem to ascertain whether first enlistment people with only this limited training can successfully perform maintenance. (See recommendation F, page 20).

13. FPJPA should be developed for at least two other similar equipments for the same career field to ascertain whether or not personnel receiving the above training and experience can, in fact, do effective maintenance on new systems with a minimum of equipment orientation on new equipments. (See recommendation G, page 20).

14. If the above two recommendations are tried and are successful, develop FPJPA for troubleshooting for all the systems maintained by this one career field should be developed. Later other career fields should be completely converted to the modified TO training system recommended in this report. (See recommendation H, page 20).

15. An indepth study should be made of the *impact* on the Air Force personnel and training system of the entire recommended modified TO/training system including FPJPA for troubleshooting. The potential gains from application of job oriented training to the above technical data mix should be included in this study. (See recommendation Q, page 30).

16. An indepth study should be made of the potential of FPJPA for the rapid buildup of forces in cases of national emergency. (See recommendation I, page 24).

17. An indepth study of the data needs of the supply and transportation specialists should be given consideration. This study should start with a task identification and analyses of the jobs of these specialists. (See recommendation E, page 17).

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Table 4. New and Traditio

(1) Levels of Maintenance Covered	(2) Types of Task Guidance	(3) Traditional Technical Order Categories	(4) SIMS Concept Categories	(5) MIL-M-38799 Categories	(6) MIL-M-38800 Categories
Organizational		X	X	X	X
Intermediate		X	X	X	–
	Non-troubleshooting tasks Such as: Checkout, Align, Adjust Calibrate, Remove Replace Repair	Type C Procedures	Type C Procedures	–	Type B Procedures
	Troubleshooting Task Directions	Symptom-Cause Charts Logic Diagrams	Type B MDC	• Type A MDC	
	Troubleshooting Task Support Information	Block Diagrams Schematics Flow Diagrams Normal readings and/or Tolerance charts	Blocked Schematics	• Keyed Schematics	
		Theory of Operation	Blocked Information	• Keyed Information	
		Pictorial Location Diagrams	• Pictorials with grids		
		• Aircraft Wiring Diagrams • Illustrated Parts Breakdown (IPBs)			
	Misc Information	• Preservation, shipping and storage			

Type A Procedures – Step-by-step instructions in standard language for all tasks of the job; the instructions are keyed to an accompanying location pictorial; the task content of the job and the content of the procedures all determined by a structured task identification and analysis system.

Type B Procedures – Step-by-step instructions in standard language for most tasks of the job; the instructions all keyed to an accompanying location pictorial; but produced without the benefit of the task identification and analysis criteria.

Type C Procedures – Step-by-step instructions not in standard language with few pictorials.

Table 4. **New and Traditional Categories of Maintenance Technical Data and Their Relationships to Air Force User Factors**

(5) MIL-M-38799 Categories	(6) MIL-M-38800 Categories	(7) AFHRL FPJPA Categories	(8) Recommended Mix of Categories	(9) Maintenance AFSC's Current Training Total 162,843				(10) Maintenance AFSC's Modified Training			
				1st Enlistment 75,744		Beyond 1st 87,099		1st Enlistment		Beyond 1st Enlistment	
X	X	X	X	3	5	5	7	3	5	5	7
X	–	X	X	28K	48K	42K	45K				
				N	R	R	F	N	N	R	F
	Type B Procedures			R	R	F	F	N	R	F	F
		• Type A Procedures (FPJPA)	•	R	F	F	F	F	F	F	F
				N	R	R	R	N	N	R	R
				N	R	R	F	N	N	R	F
Type A MDC			•	N	F	F	F	N	N	F	F
				N	R	R	F	N	N	R	F
				N	R	R	F	N	N	R	F
				N	R	R	F	N	N	R	F
				N	R	R	F	N	N	R	F
				N	R	F	F	N	N	F	F
Keyed Schematics			•	N	R	F	F	N	N	F	F
				N	R	R	R	N	N	R	R
				N	R	F	F	N	N	F	F
Keyed Information			•	N	R	F	F	N	N	F	F
				N	R	F	F	N	N	R	F
			•	N	R	F	F	N	N	R	F
			•	N	R	R	F	N	N	R	F
			•	N	R	F	F	N	R	F	F
		• FPJPA for Trouble-shooting (Type A Procedures)	•	R	F	F	F	R	F	F	F
			•	N	R	R	F	N	N	R	F

Type A MDC (Maintenance Dependency Charts) – Location pictorials have been added for all functional units and components mentioned in MDC.

Type B MDC – Tradition MDCs without location pictorials.

(10) Maintenance AFSC's Modified Training			(11) Supply 25,788	(12) Transportation 17,639	(13) Operators 10,954	(14) Engineers 6,950	(15) Curriculum Planners		(16) Trainers		(17) Trainees		(18) Administrators
ment	Beyond 1st Enlistment												
5	5	7					3	Adv	3	Adv	3	Adv	
N	R	F											
R	F	F											
F	F	F			S		S	S	S	S	S	S	S
N	R	R											
N	R	F											
N	R	F											
N	F	F				S	S	S		S		S	S
N	R	F											
N	R	F											
N	R	F											
N	R	F											
N	F	F											
N	F	F				S	S	S		S		S	S
N	R	R											
N	F	F											
N	F	F				S	S	S		S		S	S
N	R	F											
N	R	F				S	S	S		S		S	S
N	R	F				S	S	S		S		S	S
R	F	F	S		S	S	S	S	S	S	S	S	S
F	F	F											
N	R	F	S		S		S	S	S	S	S	S	S

N = Data not effective with type of personnel indicated.

R = Data reasonably effective with type of personnel indicated.

F = Data fully effective with type of personnel indicated.

S = Satisfies the requirements of user indicated.

X = Item applies.

• = Categories of data for Optimum Mix.